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I HEREBY CERTIFY that annexed hereto is a true copy of
documents filed in connection with the following patent
application:

Application No. S990765

Date of filing 13 September 1999

Applicant COMMERGY TECHNOLOGIES
LIMITED, an Irish company of 133
Lansdowne Park, Ballsbridge, Dublin 4,
Ireland.

PRIORITY DOCUMENT

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Dated this 23 day of October, 2000.



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5. Statement of right to be granted a patent (Sec

6. Items accompanying this Request

- (i) [X] prescribed filing fee (IRP 50)
- (ii) [] specification containing a description
[X] specification containing a description
[X] Drawings referred to in description
- (iii) [] An abstract
- (iv) [] Copy of previous application(s) whose
claimed
- (v) [] Translation of previous application
priority is claimed
- (vi) [] Authorisation of Agent (this may be
below if this Request is signed by t

7. Divisional Application(s)

The following information is applicable to the pre
which is made under Section 24 -

Earlier Application No.
Filing Date:

8. Agent

The following is authorised to act as agent in
connected with the obtaining of a patent to whi
relates and in relation to any patent granted -

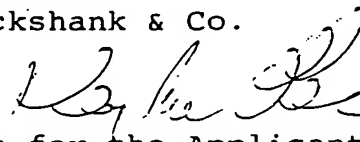
Name & Address

Cruickshank & Co. at their address recorded for t
the Register of Patent Agents is hereby appoi
address for service, presently 1 Holles Street, L

9. Address for service (if different from that at

Signed Cruickshank & Co.

By:-



Executive.

Agents for the Applicant

Date September 13, 1999.

increase with temperature. This reduction in operating temperature is achieved by coupling the components to an external heat sink using conductive and electrically-insulating materials. This heat sink dissipates heat by convection, either natural or using forced air or other fluid, and is typically made of metal with multiple fins in order to achieve a high value of surface area for the cooling air or other fluid. Many modules of this type are constructed as a base-plate which can be easily mounted in close thermal contact with the heat sink. An implementation using this approach is as described in US Patent Specification 5075821 (Donnel.).

10

Given the requirement for close packing of printed circuit "cards" in a module, there is a requirement for low-profile power conversion modules. A heat sink mounted above the module adds to the effective profile of the module, and heat sinks attached to the sides of the module reduces the effective area available for the mounting of components on the printed circuit "card".

15

The requirement for external heat sinks (without having to reduce the power capability of the converter module) may be reduced or eliminated by improving the efficiency of the module and/or by improving the thermal design of the module and its interface with the printed circuit "card" on which it is mounted.

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A number of techniques is available to improve efficiency, and improvements in efficiency are facilitated by continuing development of power semiconductor devices with higher performance in terms of lower conduction and switching losses. Power devices allow synchronous rectification of the outputs from a transformer, and power devices, used as synchronous rectifiers, can achieve a very much

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Statements of invention

According to the invention there is provided a printed circuit board assembly comprising a plurality of heat-generating thermally conductive components on the board characterised in that at least two of the components are thermally conductive elements.

Ideally the components with different heat dissipating properties and/or heat outputs, in use, are linked.

10

Preferably the components having high heat generation also have high surface area allowing for efficient heat dissipation. The overall profile of the board is of a minimum possible having regard to the highest components being used on the board and in which heat dissipation elements such as heatsinks are used on the components while not increasing the overall profile of the board.

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A particularly advantageous construction arrangement may involve placing a component with high heat generation on the opposite side of the board from a component with high heat dissipation capability (i.e. low thermal resistance) and achieving good thermal coupling between the two.

20

Ideally, thermal vias are incorporated in the board, or alternatively the components are thermally connected by pins having a high thermal conductivity.

In one embodiment of the invention there is provided a DC to DC converter comprising input devices, a transformer, rectifiers and output inductors forming high

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Alternatively, if the bottom face of the board is to be conduction-cooled by a printed circuit "card" on which it is mounted, then the output rectifier below the board may provide an element of cooling for the magnetic core mounted above the board.

Detailed Description of the Invention

The invention will be more clearly understood from the following description of one embodiment thereof, given by way of example only described with reference to the accompanying drawings in which:

Fig. 1 is plan view of a DC to DC converter according to the invention.

Fig 2 is a side view of the DC to DC converter of Fig 1, and

Fig. 3 is a plan partially diagrammatic view of an inductor used in the converter of Fig. 1 and 2.

Referring to the drawings and initially to Figs. 1 and 2, there is provided a DC to DC converter indicated generally by the reference numeral 1 having a printed circuit board 2 incorporating thermal vias formed by holes 3. Mounted above the board 2 are input switches 4 which are mounted above the board 2 and are covered by a heat sink 5. Input capacitors and controls 6 which are consuming devices are typically mounted below the board 2. Also mounted below board 2 and not shown in any detail is a transformer 7 and output

between the windings and the magnetic materials. This may be achieved by a thin layer of conformable thermally-conductive but electrically-insulating material (e.g., GapPad™ from Bergquist Corporation) between the wire or planar windings and the inner faces of the ferrite material, as an alternative to use of thermally-conductive adhesives or to potting of the magnetic assemblies.

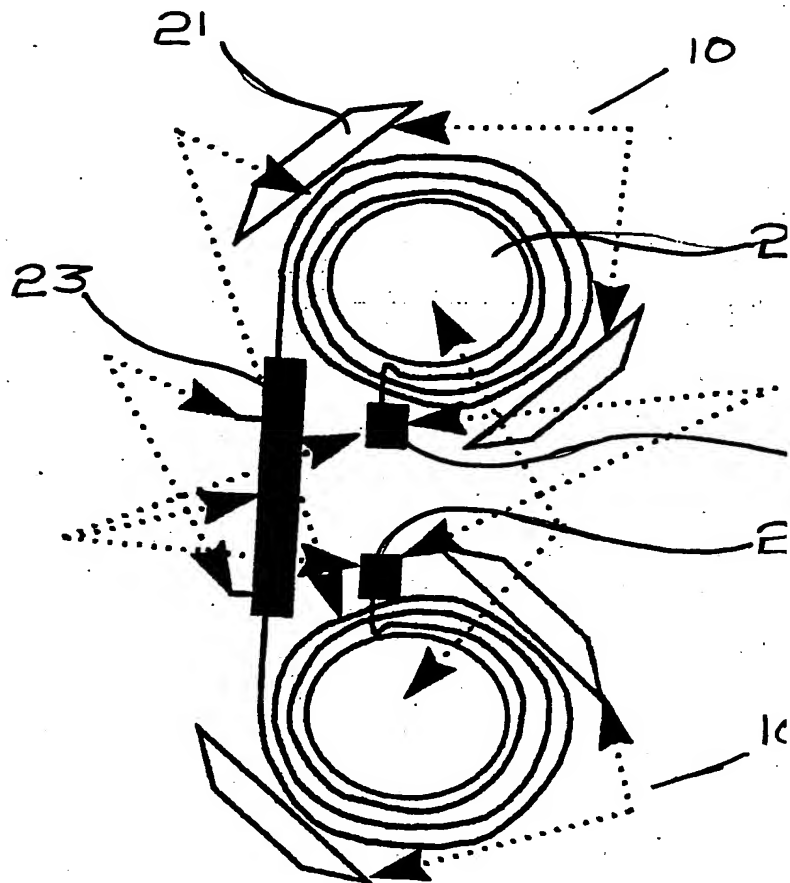
It will be appreciated that ferrite materials typically have thermal conductivity in the range of 4 to 7 WmK⁻¹. Ferrite assemblies can thus serve effectively as heat sinks for themselves for components thermally coupled to them.

In this implementation, the ferrite elements are thermally coupled by a thin sheet (and/or adhesive) of material to the synchronous rectifying elements which are mounted below the board. This mounting approach allows the synchronous rectifying elements typically in small surface-mount packages less than 10 mm square to be mounted with wide spacing across the printed circuit board within the module, thus avoiding "hot spots". With currently available planar magnetic structures, this approach allows the overall module height to be constrained to the range of 10 to 15 mm, which is preferred in order to achieve overall dimensional requirements.

Further heat-sinking for such synchronous rectifying elements is achieved by using wide pins to connect the board on which such elements are mounted to a heat sink (planar or conventional) used in the transformer and output inductors.

A further development involves use of the printed-circuit card on which the synchronous rectifying elements are mounted as part of the heat-sinking design. The module typically is r

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planar magnetic element 20 and the surface mount package which is important in many applications.

Referring now to Figs. 2 to 4 the planar magnetic element 20 comprises a magnetic
5 core material 25 in one or more sections and typically also incorporates a printed
circuit board 26 which carries tracks in the form of windings or access terminators for
wire based windings. The printed circuit boards 26 carry plugs 27 for mounting in
upstanding sockets 28 on the printed circuit board 2. It will be seen therefore that
the planar magnetic element 25 is mounted in spaced apart relationship with the
10 printed circuit board 2 and thus provides gaps or spaces for components. Obviously
lower profile components must be mounted below the inner magnetic core material
sections and other components may be placed in other portions. It is envisaged that
the planar magnetic element may incorporate conformable electrically insulating and
thermally conductive material 29.

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An important aspect of this assembly is that the planar magnetic element 20 is easily
pluggable into the printed circuit board 2. This is an important design consideration in
many applications.

20 The term 'conformable' means that the material will generally conform to the
irregularities of for example a printed circuit board. The GAP PAD material
provides efficient heat transfer from the surface of a printed circuit board which may
have some variations in solder thickness or other non-uniformities on the surface.
Also it will be appreciated that the manufacturing process may require that one or
25 more of the printed circuit boards be passed initially to a wave soldering process.

This would be particularly the case with the main printed circuit board in order to fill

~~the vias with solder prior to application of for example, surface mount devices~~

which, in turn, may involve a reflow process. A thermally conductive substrate may be used for the main printed circuit board. It will also be appreciated that selective

5 use of a thermally conductive and electrically insulating conformable material will allow devices at different electrical potentials to use the same heat dissipation

material joined together. For example, the selective use of this approach covering all of effectively the heat sink with insulating material but having selected areas of

10 heat spreaders topped by, for example, a conformable material such as that sold under the Trade Mark GAP PAD allows for the transfer of heat from surface mount

devices to the reverse side of the board or heat sink side of the board. It will also facilitate the use of through hole components in those areas removed for example

from heat spreading plates and the like. It is also possible to ensure that isolation gaps can be maintained between heat spreading grounded to the input side and

15 those grounded to the output side and any relevant component.

It is envisaged that the overall assembly by clamped or otherwise secured so that some compression force is maintained on relative sections of the conformable material.

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One of the advantages of the construction according to the present invention where planar magnetic elements are stacked above surface mounted devices is it creates

the opportunity for thermal coupling between the planar elements and the power devices. It will be readily appreciated that the thermal conductivity in ferrites and

25 other magnetic elements can be such as to achieve improved cooling particularly

under transient conditions of the semi-conductor devices. It will be appreciated that the thermal conductivity in most ferrites is of the order of 4W/mK to 7W/mK. Used in a planar magnetic structure with large ferrite cross-sectional area this level of thermal conductivity can be sufficient to achieve some material reduction in temperature of attached or adjacent semi-conductor devices. It will be appreciated that the overall thermal resistance of the assembly will of course be materially lower than that of the ferrite alone because the effect of the endpieces, spreading between the upper and lower of the pieces and of the thermal conductivity of the winding section in the planar magnetic device. The magnetic material will facilitate the transfer from the semi-conductor devices to any additional heat sinks for example located adjacent to the planar magnetic device.

The further advantages of this construction is that the planar magnetic elements may also provide electrical screening since grounding of the magnetic material which typically has a moderate level of electrical conductivity will achieve this.

It is envisaged that thermal conductivity to the planar magnetic assembly may also be facilitated by the use of a conformable material such as that sold under the "Gap Pad" Trade Mark to improve thermal conductivity between the winding and the

magnetic comb material on one or indeed more likely both faces. This can reduce the overall thermal impedance between the faces of the planar magnetic components.

It will be also be appreciated that in many cases operating the magnetic material in a planar magnetic component at an augmented temperature may give improved

performance with lower losses in the magnetic material albeit somewhat offset by higher losses in conductors. In this case, thermal coupling between a semiconductor devices and a planar magnetic assembly is advantageous for the overall performance of the circuit.

5

It is also envisaged that in certain instances it may be advantageous for the planar magnetic structure to be mounted so that the magnetic elements are almost flush with the main printed circuit board and that that part of the winding structure not covered by the magnetic elements be used for heat transfer. A further variation in this approach would be for the planar magnetic assembly to be used in association again with some conformable electrically thermally conductive and electrically insulated material. It is equally possible to transfer heat from components mounted below the main printed circuit board with heat conducted to the upper face of the printed circuit board by means of the via holes or by means of thermally conductive substrate material incorporated in the main printed circuit board. It is also envisaged that by the use of the structures there may not necessarily be a need to have any lower heat sinks or associated layers of thermally conductive material as shown. It is also envisaged that instead of conformable thermally conductive material that this may be replaced by a rigid material possibly with a covering of grease or phase-change material if relative flatness and co-planarity of adjoining surfaces can be guaranteed within close tolerances.

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The use of the planar magnetic element positioned near or over heat generating devices acts as a natural heat sink for the heat generating devices. This is due to the fact that the planar magnetic element have associated with each ferrite core which

have heat dissipative properties depending on the type of ferrite used.

In some cases it may be desirable to have a gap or some separation between the planar magnetic elements and the heat generating elements, in which case the conformable electrically and thermally insulating material may be used between the planar magnetic elements and the heat generating semi-conductor elements. Then if an additional heat sink is to be provided such a heat sink would be utilised entirely for heat dissipation in the planar magnetic element.

It will be appreciated that by applying the conformable electrically insulating and thermally conductive material beneath the printed circuit board that extremely efficient heat dissipation may be achieved.

In the specification the terms "comprise, comprises, comprised and comprising" or any variation thereof and the terms "include, includes, included and including" or any variation thereof are considered to be totally interchangeable and they should all be afforded the widest possible interpretation and vice versa.

The invention is not limited to the embodiment hereinbefore described, but may be varied in both construction and detail.

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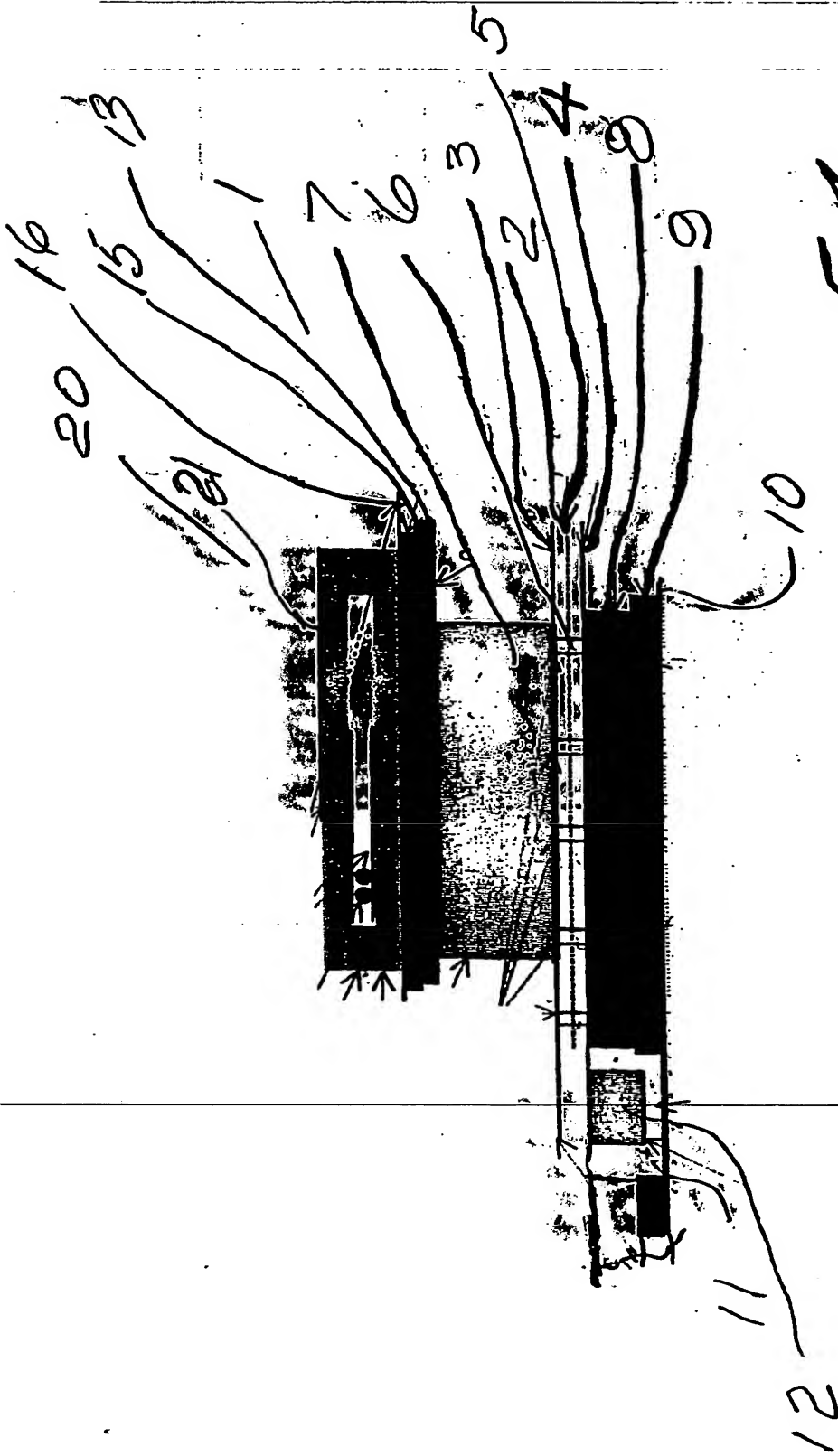


FIG 1

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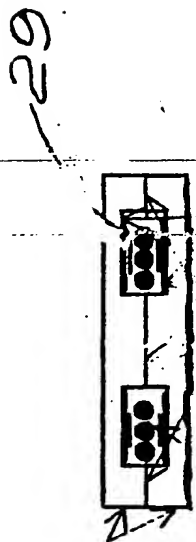


Fig 4

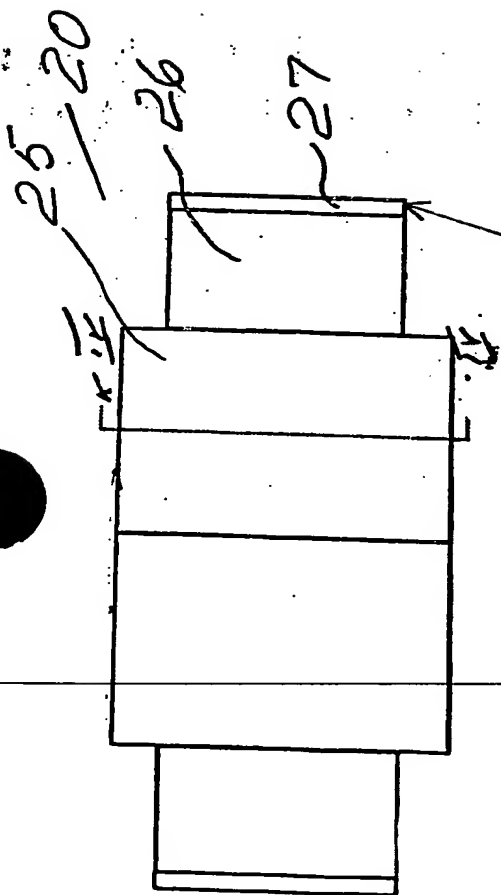


Fig 3

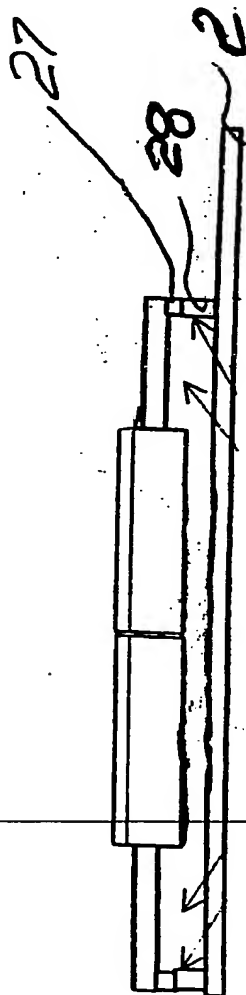


Fig 2

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